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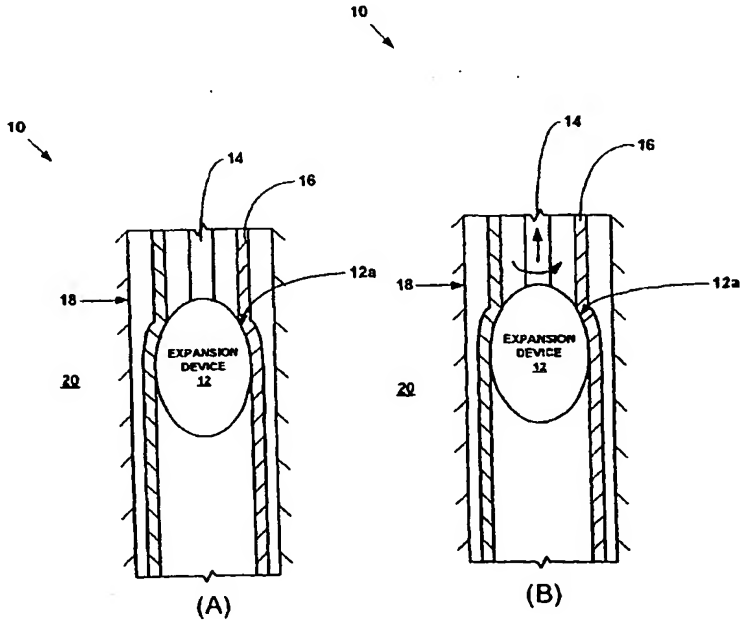
Declaration under Rule 4.17:
— *of inventorship (Rule 4.17(iv)) for US only*

[Continued on next page]

(54) Title: LUBRICATION SYSTEM FOR RADIALLY EXPANDING TUBULAR MEMBERS



(57) Abstract: A lubrication system for lubricating an interface (22) between one or more expansion surfaces (12 a) of an expansion device (12) and one or more interior surfaces (16a) of a tubular member (16) during a radial expansion of the tubular member (16) using the expansion device (12).

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INTERNATIONAL SEARCH REPORT

International application No.
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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
none

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Please See Continuation Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	US 6,557,640 B1 (COOK et al) 06 May 2003 (06/05/2003), see entire document.	1-3,6-9,12-15,18-37,65,66,68,70-72,125-128,138,141-145 and 147-151
XP	US 6,568,471 B1 (COOK et al) 27 May 2003 (27/05/2003), see entire document.	21-23,43-45,65 and 66

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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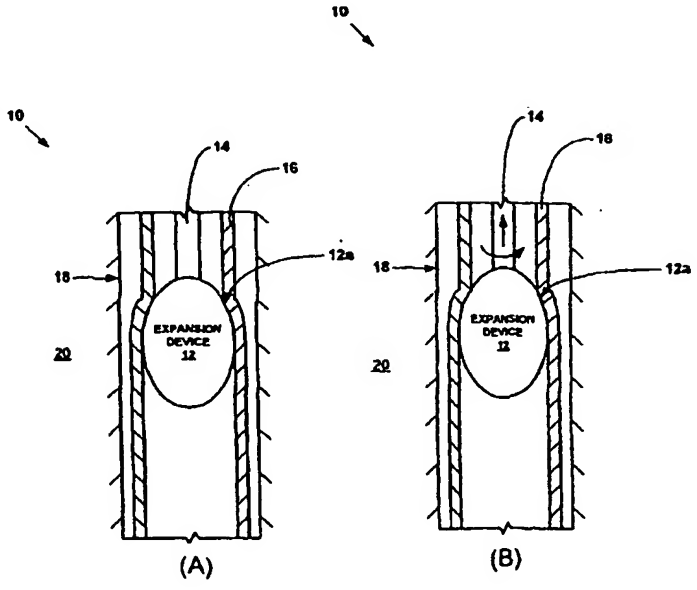
(54) Title: LUBRICATION SYSTEM FOR RADIALLY EXPANDING TUBULAR MEMBERS



(57) Abstract: A lubrication system for lubricating an interface (22) between one or more expansion surfaces (12 a) of an expansion device (12) and one or more interior surfaces (16a) of a tubular member (16) during a radial expansion of the tubular member (16) using the expansion device (12).

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AMENDED CLAIMS

[Received by the International Bureau on 22 April 2005 (22.04.05);
original claims 1-152 replaced by amended claims 1-170]

1. An expansion cone for radially expanding multiple tubular members comprising:

a body having an annular outer peripheral surface;

at least a portion of the surface being textured with friction reducing reliefs recessed into the surface.

2. The expansion cone as defined in claim 1 wherein the surface is a knurled surface.

3. The expansion cone as defined in claim 1 wherein the surface is a laser dimpled surface.

4. The expansion cone as defined in claim 1 wherein the surface is a pitted and sprayed surface.

5. The expansion cone as defined in claim 4 wherein the body includes the pitted surface formed of a first material, the pitted surface being sprayed with a second friction reducing material and the sprayed surface being partially removed sufficient to expose some of the first and second materials.

6. The expansion cone as defined in claim 1 wherein the surface is an etched surface.

7. A method for radially expanding a tubular member comprising:

providing a tubular member having an inside diameter;

providing an expansion cone having an annular outer peripheral surface including a diameter greater than the inside diameter of the tubular member;

texturing the outer peripheral surface with friction reducing reliefs recessed into the surface; and

moving the expansion cone axially through the tubular member for radially expanding and plastically deforming the tubular member.

8. The method as defined in claim 7 wherein the surface is a knurled surface.

9. The method as defined in claim 7 wherein the surface is a laser dimpled surface.

10. The method as defined in claim 7 wherein the surface is a pitted and sprayed surface.

11. The method as defined in claim 7 further comprising:

pitting the outer peripheral surface;

spraying the surface; and

grinding the surface to expose both an original portion of the surface and a sprayed portion of the surface.

12. The method as defined in claim 7 wherein the surface is an etched surface.

13. A reduced friction radial expansion apparatus comprising:

a plurality of tubular members having an axial passage formed therethrough including an inside diameter;

an expansion cone having an annular outer peripheral surface including an outside diameter greater than the inside diameter of the axial passage; and

at least a portion of the outer peripheral surface being textured with friction reducing reliefs recessed into the surface.

14. The apparatus as defined in claim 13 wherein the surface is a knurled surface.

15. The apparatus as defined in claim 13 wherein the surface is a laser dimpled surface.

16. The apparatus as defined in claim 13 wherein the surface is a pitted and sprayed surface.

17. The apparatus as defined in claim 13 wherein the cone includes a pitted surface formed of a first material, the pitted surface being sprayed with a second friction reducing material and the sprayed surface being partially removed sufficient to expose some of the first and second materials.

18. The apparatus as defined in claim 13 wherein the surface is an etched surface.

19. The apparatus as defined in claim 13 wherein a low friction material is deposited in the reliefs.

20. The apparatus as defined in claim 13 wherein the outer peripheral surface includes a flush surface including a combination of portions of material of the expansion cone and portions of a low friction material deposited in the reliefs.

21. An apparatus for radially expanding and plastically deforming a tubular member, comprising:
a support member;
an expansion device coupled to an end of the support member comprising one or more expansion surfaces for engaging the tubular member during the radial expansion and plastic deformation of the tubular member; and
a lubrication system for lubricating an interface between one or more of the expansion surfaces of the expansion device and one or more interior surfaces of the tubular member.

22. The apparatus of claim 21, wherein the lubrication system comprises:
a supply of a lubricant; and
an injector for injecting the lubricant into the interface.

23. The apparatus of claim 22, wherein the supply of lubricant is provided within the expansion device.

24. The apparatus of claim 21, wherein one or more of the expansion surfaces define one or more recesses; and wherein one or more of the recesses are coupled to the injector.

25. The apparatus of claim 21, wherein the lubrication system comprises:
a lubricating film coupled to one or more of the expansion surfaces.

26. The apparatus of claim 25, wherein one or more of the expansion surfaces define one or more recesses; and wherein at least a portion of the lubricating film is deposited within one or more of the recesses.

27. The apparatus of claim 21, wherein one or more of the expansion surfaces of the expansion device define one or more recesses.

28. The apparatus of claim 27, wherein at least some of the recesses are identical to one another.

29. The apparatus of claim 27, wherein at least some of the recesses are equally spaced from one another.

30. The apparatus of claim 27, wherein a depth dimension of the recesses are non-uniform.

31. The apparatus of claim 27, wherein at least some of the recesses intersect.

32. The apparatus of claim 27, wherein the location of at least some of the recesses is randomly distributed.

33. The apparatus of claim 27, wherein the geometry of at least some of the recesses is randomly distributed.

34. The apparatus of claim 27, wherein a surface texture of at least some of the recesses is randomly distributed.

35. The apparatus of claim 27, wherein the geometry of at least some of the recesses is linear.

36. The apparatus of claim 27, wherein the geometry of at least some of the recesses is non-linear.

37. The apparatus of claim 27, wherein the interface comprises a leading edge portion and a trailing edge portion; and wherein the lubrication system provides a higher lubrication concentration in at least one of the leading and trailing edge portions.

38. The apparatus of claim 21, wherein one or more of the expansion surfaces of the expansion device define one or more recesses; and wherein the apparatus further comprises one or more lubricating ball bearings supported within at least one of the recesses.

39. The apparatus of claim 21, wherein a lubrication concentration provided by the lubrication system is varied as a function of a rate of strain of the tubular member during an operation of the apparatus.

40. The apparatus of claim 39, wherein the function comprises a linear function.

41. The apparatus of claim 39, wherein the function comprises a non-linear function.

42. The apparatus of claim 39, wherein the function comprises a step function.

43. A method for radially expanding and plastically deforming a tubular member, comprising:

radially expanding and plastically deforming the tubular member using an expansion device comprising one or more expansion surfaces; and

lubricating an interface between one or more of the expansion surfaces of the expansion device and one or more interior surfaces of the tubular member.

44. The method of claim 43, further comprising:

injecting a supply of lubricant into the interface.

45. The method of claim 44, wherein the supply of lubricant is provided within the expansion device.

46. The method of claim 43, wherein one or more of the expansion surfaces define one or more recesses; and wherein the method further comprises injecting the supply of lubricant into one or more of the recesses.

47. The method of claim 43, further comprising:
coupling a lubricating film to one or more of the expansion surfaces.

48. The method of claim 47, wherein one or more of the expansion surfaces define one or more recesses; and wherein at least a portion of the lubricating film is coupled to one or more of the recesses.

49. The method of claim 43, wherein one or more of the expansion surfaces of the expansion device define one or more recesses.

50. The method of claim 49, wherein at least some of the recesses are identical to one another.

51. The method of claim 49, wherein at least some of the recesses are equally spaced from one another.

52. The method of claim 49, wherein a depth dimension of the recesses are non-uniform.

53. The method of claim 49, wherein at least some of the recesses intersect.

54. The method of claim 49, wherein the location of at least some of the recesses is randomly distributed.

55. The method of claim 49, wherein the geometry of at least some of the recesses is randomly distributed.

56. The method of claim 49, wherein a surface texture of at least some of the recesses is randomly distributed.

57. The method of claim 49, wherein the geometry of at least some of the recesses is linear.

58. The method of claim 49, wherein the geometry of at least some of the recesses is non-linear.

59. The method of claim 49, wherein the interface comprises a leading edge portion and a trailing edge portion; and wherein the method further comprises providing a higher lubrication concentration in at least one of the leading and trailing edge portions.

60. The method of claim 43, wherein one or more of the expansion surfaces of the expansion device define one or more recesses; and wherein the method

further comprises forming one or more lubricating ball bearings within at least one of the recesses.

61. The method of claim 43, further comprising varying a lubrication concentration as a function of a rate of strain of the tubular member during the radial expansion and plastic deformation of the tubular member.

62. The method of claim 61, wherein the function comprises a linear function.

63. The method of claim 61, wherein the function comprises a non-linear function.

64. The method of claim 61, wherein the function comprises a step function.

65. A system for lubricating an interface between an expansion device and a tubular member during a radial expansion of the tubular member by the expansion device, comprising:
means for supplying a quantity of a lubricant material; and
means for injecting at least a portion of the lubricant material into the interface.

66. The system of claim 65, further comprising:
means for varying the concentration of the lubricant material within the interface.

67. A method of operating a system for lubricating an interface between an expansion device and a tubular member during a radial expansion of the tubular member by the expansion device, comprising:
determining a rate of strain of the tubular member during an operation of the expansion device; and
varying a concentration of a lubricant material within the interface during the operation of the expansion device as a function of the determined rate of strain.

68. A method of operating a system for lubricating an interface between an expansion device and a tubular member during a radial expansion of the tubular member by the expansion device, comprising:
determining one or more characteristics of the interface during an operation of the expansion device; and
varying a concentration of a lubricant material within the interface during the operation of the expansion device as a function of one or more of the determined characteristics.

69. A system for lubricating an interface between an expansion device and a tubular member during a radial expansion of the tubular member by the expansion device, comprising:

means for determining a rate of strain of the tubular member during an operation of the expansion device; and

means for varying a concentration of a lubricant material within the interface during the operation of the expansion device as a function of the determined rate of strain.

70. A system for lubricating an interface between an expansion device and a tubular member during a radial expansion of the tubular member by the expansion device, comprising:

means for determining one or more characteristics of the interface during an operation of the expansion device; and

means for varying a concentration of a lubricant material within the interface during the operation of the expansion device as a function of one or more of the determined characteristics.

71. A method of operating a system for lubricating an interface between an expansion device and a tubular member during a radial expansion of the tubular member by the expansion device, comprising:

determining one or more characteristics of the operation of the expansion device; and

varying a concentration of a lubricant material within the interface during the operation of the expansion device as a function of one or more of the determined characteristics.

72. A system for lubricating an interface between an expansion device and a tubular member during a radial expansion of the tubular member by the expansion device, comprising:

means for determining one or more characteristics of the operation of the expansion device; and

means for varying a concentration of a lubricant material within the interface during the operation of the expansion device as a function of one or more of the determined characteristics.

73. An apparatus for radially expanding and plastically deforming a tubular member, comprising:

a support member;

an expansion device coupled to an end of the support member comprising one or more expansion surfaces for engaging the tubular member during the radial expansion and plastic deformation of the tubular member, wherein at least a portion of at least one of the expansion surfaces define one or more recesses; and

a lubrication system for lubricating an interface between one or more of the expansion surfaces of the expansion device and one or more interior surfaces of the tubular member comprising:

a lubricating film coupled to at least one of the recesses of the expansion surfaces of the expansion device;

a supply of lubricant; and

an injector coupled to the supply of lubricant and at least one of the recesses of the expansion surfaces for injecting the supply of lubricant into at least one of the recesses.

74. A method for radially expanding and plastically deforming a tubular member, comprising:

radially expanding and plastically deforming the tubular member using an expansion device comprising one or more expansion surfaces, wherein one or more of the expansion surfaces define one or more recesses; and

lubricating an interface between one or more of the expansion surfaces of the expansion device and one or more interior surfaces of the tubular member by:

coating at least one of the recesses with a lubricating film; and

injecting a lubricant material into at least one of the recesses.

75. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device defining a surface texture;

a first lubricating film coupled to the expansion surface;

a second lubricating film coupled to an interior surface of the tubular member; and

a lubricating material disposed within an annulus defined between the expansion surface of the expansion device and the interior surface of the tubular member.

76. The system of claim 75, wherein a resistance to abrasion of the first lubricating film is greater than a resistance to abrasion of the second lubricating film.

77. The system of claim 75, wherein the R_a for the expansion surface is less than or equal to 60.205 nm.

78. The system of claim 75, wherein the R_z for the expansion surface is less than or equal to 1.99 nm.

79. The system of claim 75, wherein the R_a for the expansion surface is about 60.205 nm.

80. The system of claim 75, wherein the R_z for the expansion surface is about 1.99 nm.

81. The system of claim 75, wherein the R_a for the expansion surface is less than or equal to 277.930 nm.

82. The system of claim 75, wherein the R_z for the expansion surface is less than or equal to 3.13 nm.

83. The system of claim 75, wherein the R_a for the expansion surface is less than or equal to 277.930 nm and greater than or equal to 60.205 nm.

84. The system of claim 75, wherein the R_z for the expansion surface is less than or equal to 3.13 nm and greater than or equal to 1.99 nm.

85. The system of claim 75, wherein the expansion surface comprises a plateau-like surface that defines one or more relatively deep recesses.

86. The system of claim 75, wherein the first lubricating film comprises chromium nitride.

87. The system of claim 75, wherein the second lubricating film comprises PTFE.

88. The system of claim 75, wherein the expansion surface comprises DC53 tool steel.

89. The system of claim 75, wherein the coefficient of friction for the interface is less than or equal to 0.125.

90. The system of claim 75, wherein the coefficient of friction for the interface is less than 0.125.

91. The system of claim 75, wherein the coefficient of friction for the interface is less than or equal to 0.125 and greater than or equal to 0.06.

92. The system of claim 75, wherein the coefficient of friction for the interface is less than or equal to 0.06.

93. The system of claim 75, wherein the expansion surface comprises a polished surface.

94. The system of claim 75, wherein the forces required to overcome friction during the radial expansion and plastic deformation of the tubular member are less than or equal to 45% of the total forces required to radially expand and plastically deform the tubular member.

95. The system of claim 75, wherein the forces required to overcome friction during the radial expansion and plastic deformation of the tubular member are less than 45% of the total forces required to radially expand and plastically deform the tubular member.

96. The system of claim 75, wherein the forces required to overcome friction during the radial expansion and plastic deformation of the tubular member are less than or equal to 45% and greater than or equal to 8% of the total forces required to radially expand and plastically deform the tubular member.

97. The system of claim 75, wherein the forces required to overcome friction during the radial expansion and plastic deformation of the tubular member are less than or equal to 8% of the total forces required to radially expand and plastically deform the tubular member.

98. The system of claim 75, wherein the bearing ratio of the expansion surface varies less than about 15%.

99. The system of claim 75, wherein the bearing ratio of the expansion surface of the expansion device is greater than 75% on 60% of the R_z surface roughness.

100. A method of lubricating an interface between an expansion surface of an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

texturing the expansion surface;

coupling a first lubricating film coupled to the expansion surface;

coupling a second lubricating film to an interior surface of the tubular member; and

disposing a lubricating material within an annulus defined between the expansion surface of the expansion device and the interior surface of the tubular member.

101. The method of claim 100, wherein a resistance to abrasion of the first lubricating film is greater than a resistance to abrasion of the second lubricating film.

102. The method of claim 100, wherein the R_a for the expansion surface is less than or equal to 60.205 nm.

103. The method of claim 100, wherein the R_z for the expansion surface is less than or equal to 1.99 nm.

104. The method of claim 100, wherein the R_a for the expansion surface is about 60.205 nm.

105. The method of claim 100, wherein the R_z for the expansion surface is about 1.99 nm.

106. The method of claim 100, wherein the R_a for the expansion surface is less than or equal to 277.930 nm.

107. The method of claim 100, wherein the R_z for the expansion surface is less than or equal to 3.13 nm.

108. The method of claim 100, wherein the R_a for the expansion surface is less than or equal to 277.930 nm and greater than or equal to 60.205 nm.

109. The method of claim 100, wherein the R_z for the expansion surface is less than or equal to 3.13 nm and greater than or equal to 1.99 nm.

110. The method of claim 100, wherein the expansion surface comprises a plateau-like surface that defines one or more relatively deep recesses.

111. The method of claim 100, wherein the first lubricating film comprises chromium nitride.

112. The method of claim 100, wherein the second lubricating film comprises PTFE.

113. The method of claim 100, wherein the expansion surface comprises DC53 tool steel.

114. The method of claim 100, wherein the coefficient of friction for the interface is less than or equal to 0.125.

115. The method of claim 100, wherein the coefficient of friction for the interface is less than or equal to 0.125 and greater than or equal to 0.06.

116. The method of claim 100, wherein the coefficient of friction for the interface is less than 0.125 and greater than or equal to 0.06.

117. The method of claim 100, wherein the coefficient of friction for the interface is less or equal to 0.06.

118. The method of claim 100, further comprising polishing the expansion surface.

119. The method of claim 100, wherein the forces required to overcome friction during the radial expansion and plastic deformation of the tubular member are less than or equal to 45% of the total forces required to radially expand and plastically deform the tubular member.

120. The method of claim 100, wherein the forces required to overcome friction during the radial expansion and plastic deformation of the tubular member are less than 45% of the total forces required to radially expand and plastically deform the tubular member.

121. The method of claim 100, wherein the forces required to overcome friction during the radial expansion and plastic deformation of the tubular member are less than or equal to 45% and greater than or equal to 8% of the total forces required to radially expand and plastically deform the tubular member.

122. The method of claim 100, wherein the forces required to overcome friction during the radial expansion and plastic deformation of the tubular member are less than or equal to 8% of the total forces required to radially expand and plastically deform the tubular member.

123. The method of claim 100, wherein the bearing ratio of the expansion surface varies less than about 15%.

124. The method of claim 100, wherein the bearing ratio of the expansion surface of the expansion device is greater than 75% on 60% of the R_z surface roughness.

125. A system for radially expanding and plastically deforming a tubular member, wherein the amount of energy required to overcome frictional forces during the radial expansion and plastic deformation of the tubular member is less than or equal to 45% of the total amount of energy required to radially expand and plastically deform the tubular member.

126. A system for radially expanding and plastically deforming a tubular member comprising an expansion device, wherein the coefficient of friction between the expansion device and the tubular member during the radial expansion and plastic deformation of the tubular member is less than or equal to 0.125.

127. A system for radially expanding and plastically deforming a tubular member, wherein the amount of energy required to overcome frictional forces during the radial expansion and plastic deformation of the tubular member is less than or equal to

45% and greater than or equal to 8% of the total amount of energy required to radially expand and plastically deform the tubular member.

128. A system for radially expanding and plastically deforming a tubular member comprising an expansion device, wherein the coefficient of friction between the expansion device and the tubular member during the radial expansion and plastic deformation of the tubular member is less than or equal to 0.06.

129. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device defining a surface texture;

a first lubricating film coupled to the expansion surface; and

a second lubricating film coupled to an interior surface of the tubular member;

wherein a resistance to abrasion of the first lubricating film is greater than a resistance to abrasion of the second lubricating film.

130. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device defining a surface texture;

wherein the R_a for the expansion surface is less than or equal to 60.205 nm.

131. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device defining a surface texture;

wherein the R_z for the expansion surface is less than or equal to 1.99 nm.

132. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device defining a surface texture;

wherein the R_a for the expansion surface is about 60.205 nm.

133. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device defining a surface texture;

wherein the R_z for the expansion surface is about 1.99 nm.

134. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device defining a surface texture;

wherein the R_a for the expansion surface is less than or equal to 277.930 nm.

135. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device defining a surface texture;

wherein the R_z for the expansion surface is less than or equal to 3.13 nm.

136. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device defining a surface texture;

wherein the R_a for the expansion surface is less than or equal to 277.930 nm and greater than or equal to 60.205 nm.

137. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device defining a surface texture;

wherein the R_z for the expansion surface is less than or equal to 3.13 nm and greater than or equal to 1.99 nm.

138. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device defining a surface texture;

wherein the expansion surface comprises a plateau-like surface that defines one or more relatively deep recesses.

139. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device defining a surface texture; and

a lubricating film coupled to the expansion surface;

wherein the first lubricating film comprises chromium nitride.

140. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device defining a surface texture; and

a lubricating film coupled to an interior surface of the tubular member;

wherein the lubricating film comprises PTFE.

141. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device defining a surface texture;

wherein the expansion surface comprises DC53 tool steel.

142. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device;

wherein the coefficient of friction for the interface is less than or equal to 0.125.

143. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device;

wherein the coefficient of friction for the interface is less than 0.125.

144. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device;

wherein the coefficient of friction for the interface is less than or equal to 0.125 and greater than or equal to 0.06.

145. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device;

wherein the coefficient of friction for the interface is less than or equal to 0.06.

146. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device;

wherein the expansion surface comprises a polished surface.

147. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device;

wherein the forces required to overcome friction during the radial expansion and plastic deformation of the tubular member are less than or equal to 45% of the total forces required to radially expand and plastically deform the tubular member.

148. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device;

wherein the forces required to overcome friction during the radial expansion and plastic deformation of the tubular member are less than 45% of the total forces required to radially expand and plastically deform the tubular member.

149. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device;

wherein the forces required to overcome friction during the radial expansion and plastic deformation of the tubular member are less than or equal to 45% and greater than or equal to 8% of the total forces required to radially expand and plastically deform the tubular member.

150. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device;

wherein the forces required to overcome friction during the radial expansion and plastic deformation of the tubular member are less than or equal to 8% of the total forces required to radially expand and plastically deform the tubular member.

151. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device;

wherein the bearing ratio of the expansion surface varies less than about 15%.

152. A tribological system for lubricating an interface between an expansion device and a tubular member during a radial expansion and plastic deformation of the tubular member, comprising:

an expansion surface coupled to the expansion device;

wherein the bearing ratio of the expansion surface of the expansion device is greater than 75% on 60% of the R_z surface roughness.

153. An expansion cone for radially expanding multiple tubular members comprising:

a body having an annular outer peripheral surface;

at least a portion of the surface being textured with friction reducing reliefs recessed into the surface;

wherein the surface is a pitted and sprayed surface.

154. An expansion cone for radially expanding multiple tubular members comprising:

a body having an annular outer peripheral surface;

at least a portion of the surface being textured with friction reducing reliefs recessed into the surface;

wherein the surface is a pitted and sprayed surface; and

wherein the body includes the pitted surface formed of a first material, the pitted surface being sprayed with a second friction reducing material and the sprayed surface being partially removed sufficient to expose some of the first and second materials.

155. A method for radially expanding a tubular member comprising:

providing a tubular member having an inside diameter;

providing an expansion cone having an annular outer peripheral surface including a diameter greater than the inside diameter of the tubular member;

texturing the outer peripheral surface with friction reducing reliefs recessed into the surface; and

moving the expansion cone axially through the tubular member for radially expanding and plastically deforming the tubular member;

wherein the surface is a pitted and sprayed surface.

156. A method for radially expanding a tubular member comprising:

providing a tubular member having an inside diameter;

providing an expansion cone having an annular outer peripheral surface including a diameter greater than the inside diameter of the tubular member;

texturing the outer peripheral surface with friction reducing reliefs recessed into the surface; and

moving the expansion cone axially through the tubular member for radially expanding and plastically deforming the tubular member;

pitting the outer peripheral surface;

spraying the surface; and

grinding the surface to expose both an original portion of the surface and a sprayed portion of the surface.

157. A reduced friction radial expansion apparatus comprising:

a plurality of tubular members having an axial passage formed therethrough including an inside diameter;

an expansion cone having an annular outer peripheral surface including an outside diameter greater than the inside diameter of the axial passage; and

at least a portion of the outer peripheral surface being textured with friction reducing reliefs recessed into the surface;

wherein the surface is a pitted and sprayed surface.

158. A reduced friction radial expansion apparatus comprising:

a plurality of tubular members having an axial passage formed therethrough including an inside diameter;

an expansion cone having an annular outer peripheral surface including an outside diameter greater than the inside diameter of the axial passage; and

at least a portion of the outer peripheral surface being textured with friction reducing reliefs recessed into the surface;

wherein the cone includes a pitted surface formed of a first material, the pitted surface being sprayed with a second friction reducing material and the sprayed surface being partially removed sufficient to expose some of the first and second materials.

159. An apparatus for radially expanding and plastically deforming a tubular member, comprising:

a support member;

an expansion device coupled to an end of the support member comprising one or more expansion surfaces for engaging the tubular member during the radial expansion and plastic deformation of the tubular member; and

a lubrication system for lubricating an interface between one or more of the expansion surfaces of the expansion device and one or more interior surfaces of the tubular member;

wherein one or more of the expansion surfaces of the expansion device define one or more recesses; and wherein the apparatus further comprises one or more lubricating ball bearings supported within at least one of the recesses.

160. An apparatus for radially expanding and plastically deforming a tubular member, comprising:

a support member;

an expansion device coupled to an end of the support member comprising one or more expansion surfaces for engaging the tubular member during the radial expansion and plastic deformation of the tubular member; and

a lubrication system for lubricating an interface between one or more of the expansion surfaces of the expansion device and one or more interior surfaces of the tubular member;

wherein a lubrication concentration provided by the lubrication system is varied as a function of a rate of strain of the tubular member during an operation of the apparatus.

161. An apparatus for radially expanding and plastically deforming a tubular member, comprising:

a support member;

an expansion device coupled to an end of the support member comprising one or more expansion surfaces for engaging the tubular member during the radial expansion and plastic deformation of the tubular member; and

a lubrication system for lubricating an interface between one or more of the expansion surfaces of the expansion device and one or more interior surfaces of the tubular member;

wherein a lubrication concentration provided by the lubrication system is varied as a function of a rate of strain of the tubular member during an operation of the apparatus; and

wherein the function comprises one or more of the following: a linear function, a non-linear function, or a step function.

162. A method for radially expanding and plastically deforming a tubular member, comprising:

radially expanding and plastically deforming the tubular member using an expansion device comprising one or more expansion surfaces; and

lubricating an interface between one or more of the expansion surfaces of the expansion device and one or more interior surfaces of the tubular member;

wherein one or more of the expansion surfaces define one or more recesses; and wherein the method further comprises injecting the supply of lubricant into one or more of the recesses.

163. A method for radially expanding and plastically deforming a tubular member, comprising:

radially expanding and plastically deforming the tubular member using an expansion device comprising one or more expansion surfaces;

lubricating an interface between one or more of the expansion surfaces of the expansion device and one or more interior surfaces of the tubular member; and

coupling a lubricating film to one or more of the expansion surfaces.

164. A method for radially expanding and plastically deforming a tubular member, comprising:

radially expanding and plastically deforming the tubular member using an expansion device comprising one or more expansion surfaces;

lubricating an interface between one or more of the expansion surfaces of the expansion device and one or more interior surfaces of the tubular member; and

coupling a lubricating film to one or more of the expansion surfaces;

wherein one or more of the expansion surfaces define one or more recesses; and

wherein at least a portion of the lubricating film is coupled to one or more of the recesses.

165. A method for radially expanding and plastically deforming a tubular member, comprising:

radially expanding and plastically deforming the tubular member using an expansion device comprising one or more expansion surfaces; and

lubricating an interface between one or more of the expansion surfaces of the expansion device and one or more interior surfaces of the tubular member;

wherein one or more of the expansion surfaces of the expansion device define one or more recesses.

166. A method for radially expanding and plastically deforming a tubular member, comprising:

radially expanding and plastically deforming the tubular member using an expansion device comprising one or more expansion surfaces; and

lubricating an interface between one or more of the expansion surfaces of the expansion device and one or more interior surfaces of the tubular member;

wherein one or more of the expansion surfaces of the expansion device define one or more recesses; and

wherein at least some of the recesses are identical to one another, at least some of the recesses are equally spaced from one another, a depth dimension of the recesses are non-uniform, at least some of the recesses intersect, the location of at least some of the recesses is randomly distributed, the geometry of at least some of the recesses is randomly distributed, a surface texture of at least some of the recesses

is randomly distributed, the geometry of at least some of the recesses is linear, the geometry of at least some of the recesses is non-linear, or the interface comprises a leading edge portion and a trailing edge portion.

167. A method for radially expanding and plastically deforming a tubular member, comprising:

radially expanding and plastically deforming the tubular member using an expansion device comprising one or more expansion surfaces;

lubricating an interface between one or more of the expansion surfaces of the expansion device and one or more interior surfaces of the tubular member; and

providing a higher lubrication concentration in at least one of the leading and trailing edge portions.

168. A method for radially expanding and plastically deforming a tubular member, comprising:

radially expanding and plastically deforming the tubular member using an expansion device comprising one or more expansion surfaces; and

lubricating an interface between one or more of the expansion surfaces of the expansion device and one or more interior surfaces of the tubular member;

wherein one or more of the expansion surfaces of the expansion device define one or more recesses; and wherein the method further comprises forming one or more lubricating ball bearings within at least one of the recesses.

169. A method for radially expanding and plastically deforming a tubular member, comprising:

radially expanding and plastically deforming the tubular member using an expansion device comprising one or more expansion surfaces;

lubricating an interface between one or more of the expansion surfaces of the expansion device and one or more interior surfaces of the tubular member; and

varying a lubrication concentration as a function of a rate of strain of the tubular member during the radial expansion and plastic deformation of the tubular member.

170. A method for radially expanding and plastically deforming a tubular member, comprising:

radially expanding and plastically deforming the tubular member using an expansion device comprising one or more expansion surfaces;

lubricating an interface between one or more of the expansion surfaces of the expansion device and one or more interior surfaces of the tubular member; and

varying a lubrication concentration as a function of a rate of strain of the tubular member during the radial expansion and plastic deformation of the tubular member;

wherein the function comprises at least one of a linear function, a non-linear function, or a step function.